

# ORIGINS



**Searching for Life Elsewhere in the Universe**

How Did We Get Here?

Are We Alone in the Universe?

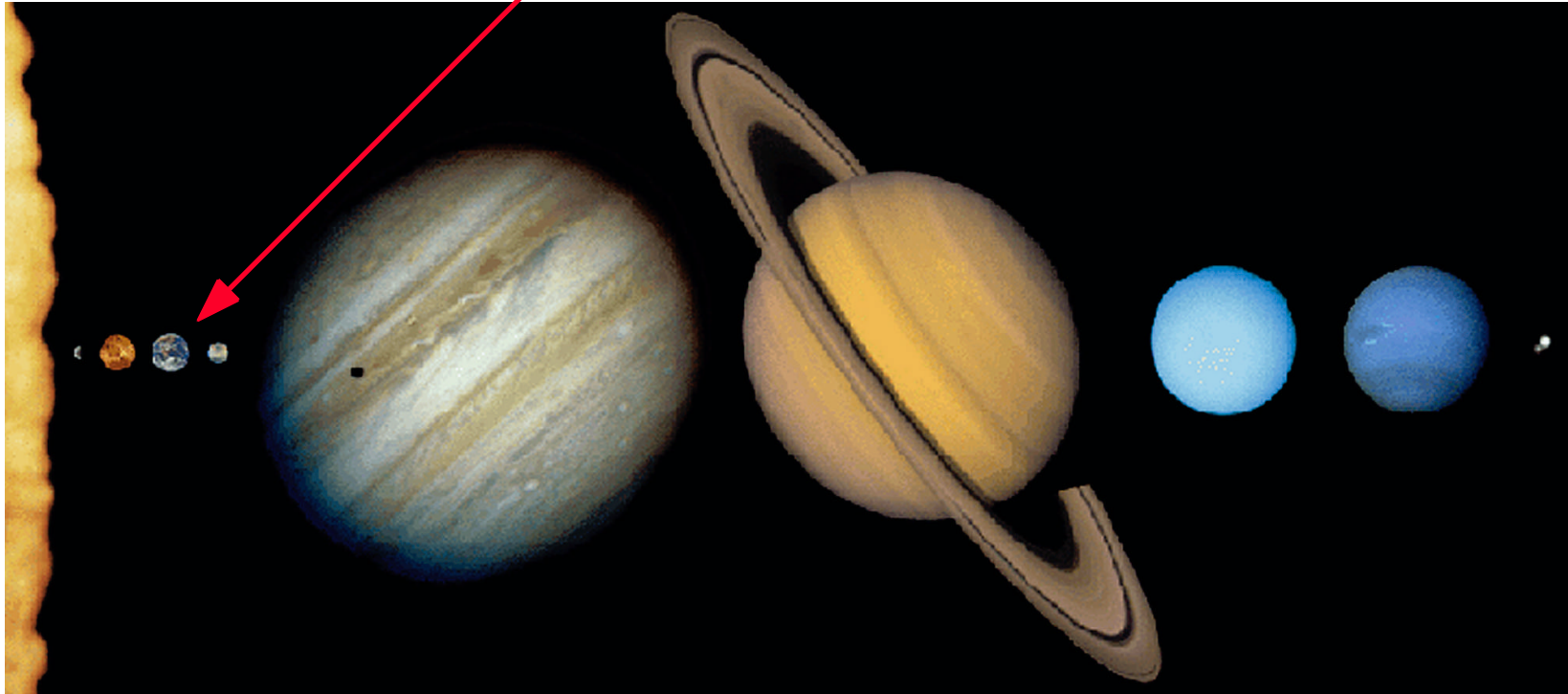
Our Generation is Privileged -- if We Accept the Challenge -- to Have the Opportunity to Answer These Timeless Questions Asked Around Ancient Campfires and in Contemporary Classrooms Today.

“If We Are Alone in the Universe, Then It Is  
an Awful Waste of Space”

-- Carl Sagan

**Looking for Life?**  
**Then Look for Planets and Their Moons**

# **The Secret is Location, Location, Location ...and Earth Has a Great Location**

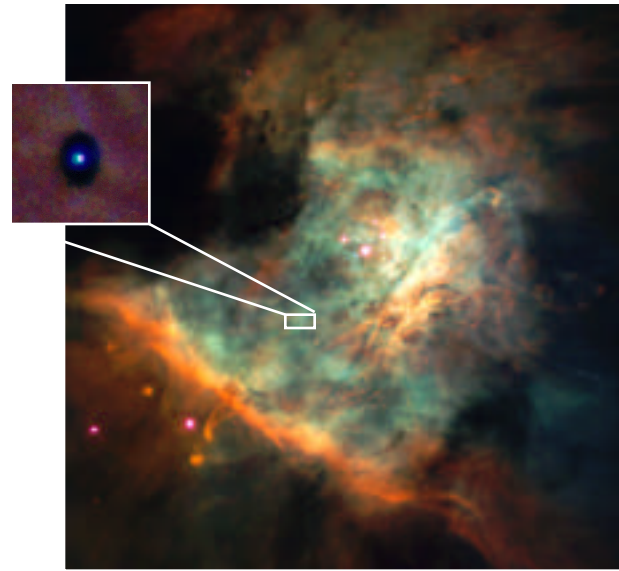


- Life cannot survive on hot stars, like our Sun. Life needs to be where it is not too hot, not too cold, like our Sun. Life needs to be where it is not too hot, not too cold, and at a distance from the star at which liquid water can exist.

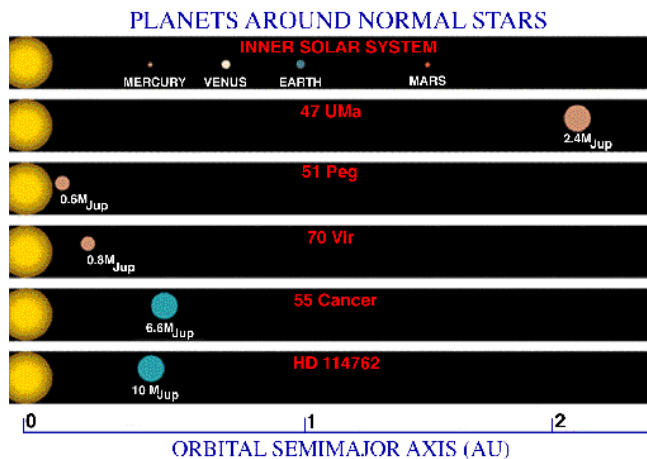
**Are There Other Planets Outside  
Our Own Solar System?**

Yes. But for now we have to rely on tell-tale signs rather than direct sightings.

Orion Nebula



We are seeing young stars evolving much like our early Sun did, before our 9 planets formed



Since late 1995, astronomers around the world have discovered -- indirectly -- a number of large (and therefore easy to detect) planets

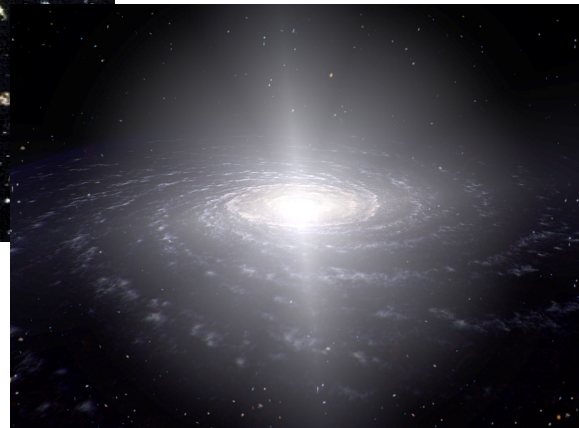
## Beyond the Global Village



NASA's Search for Other Planets



In a Universe Teeming  
with Galaxies.....



and Galaxies Teeming  
with Stars...

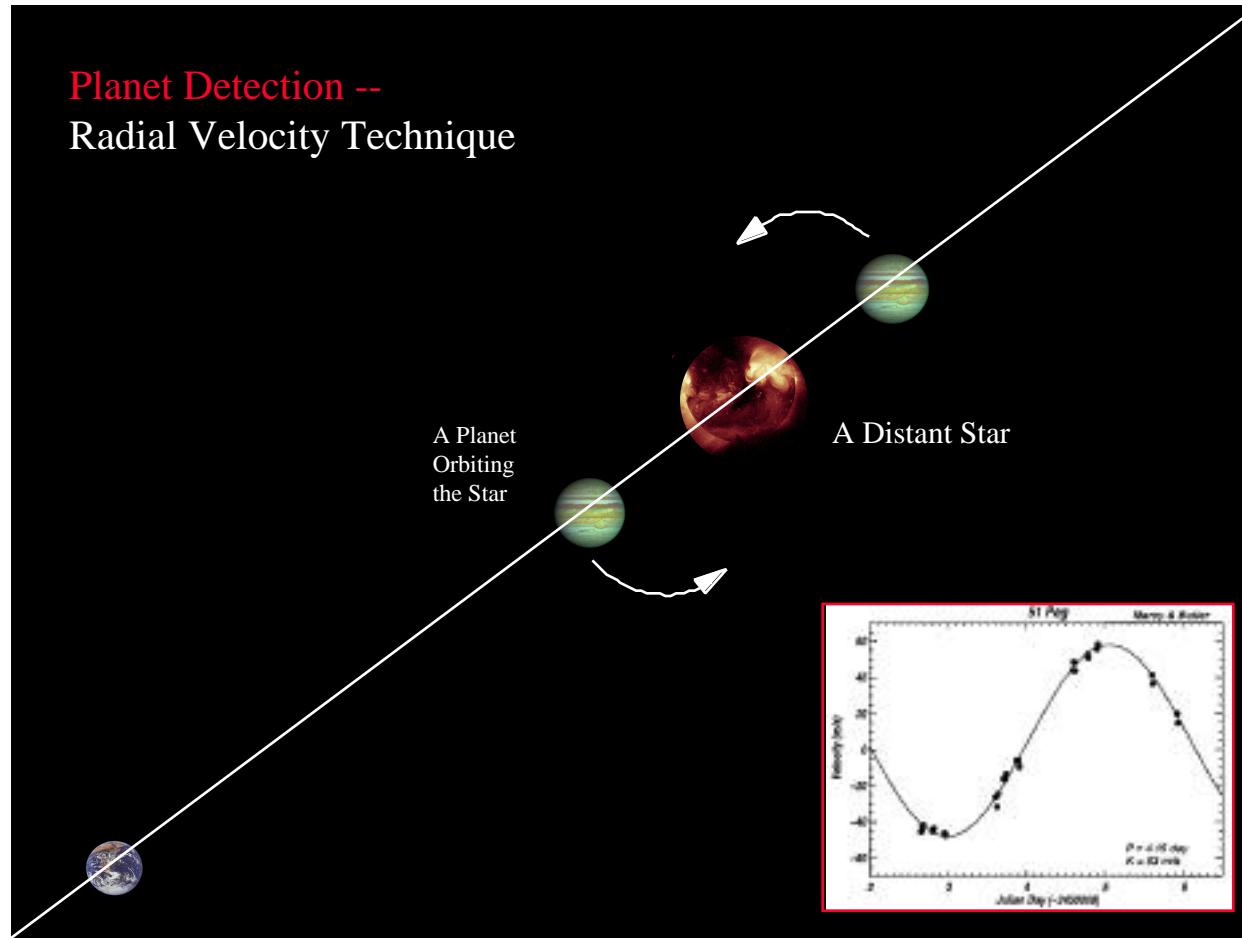


### Engaging the Human Spirit

Is There Another “Village”  
Like Earth in the Neighborhood  
... within 50 Light Years?

**Here are two INDIRECT methods of detecting a planet you can't see. Both use the fact that if there is a planet near a star, it will affect the position and velocity of the star.**

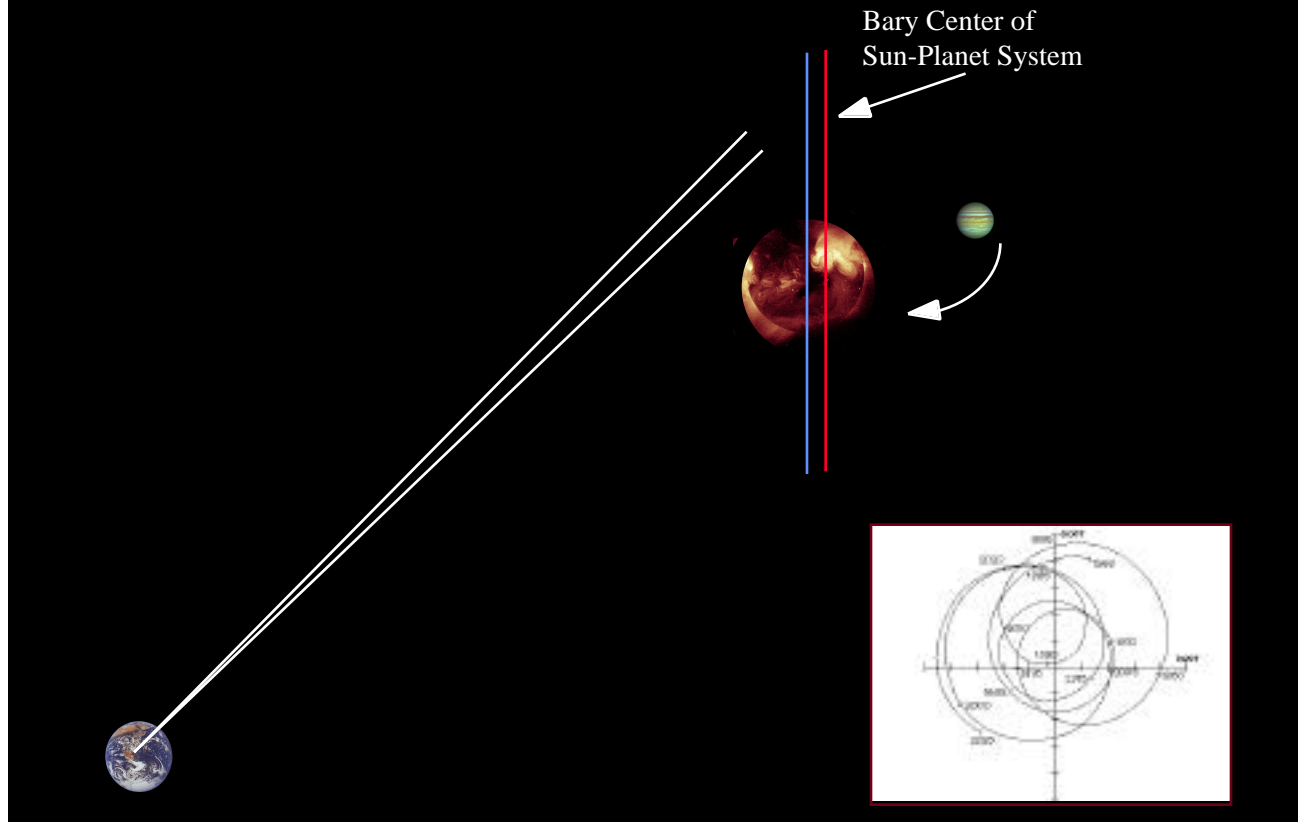
## Planet Detection -- Radial Velocity Technique



**Change in Velocity:** If a star appears to move toward us for awhile and then away from us, there might be a planet nearby pulling on the star

- Every star has a unique “fingerprint” of light
- When the stars moves **away** from us, its “fingerprint” get **redder**
- When the star moves **toward** us, its “fingerprint” gets **bluer**
- Measurement of the shift from red to blue is actually a measure of the shift in the star’s radial velocity

## Planet Detection -- Astrometric Techniques



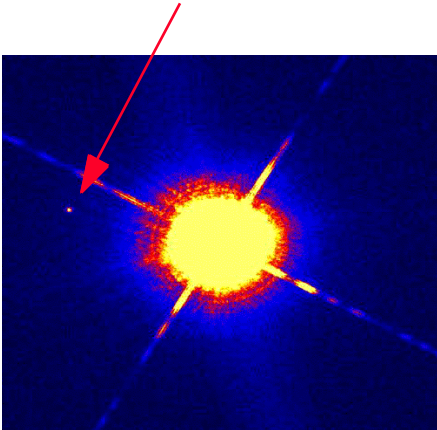
**Change in Position:** If a star “wobbles” from side to side, there might be a planet nearby, affecting it gravitationally

- Precise measurement of the position of stars (called *astrometry*) tells us the extent of the wobble and from that we can deduce the planet’s mass and orbit

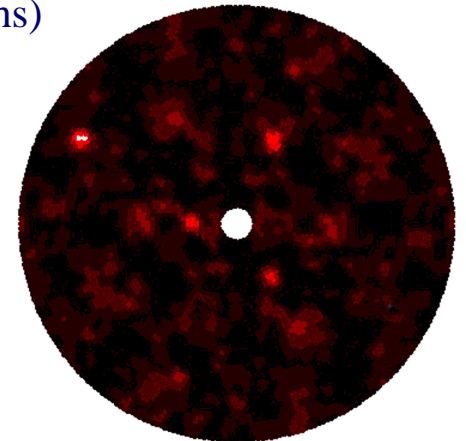
# **How Can We Detect Planets Directly?**

# A Picture is Worth A Thousand Words: Image It!

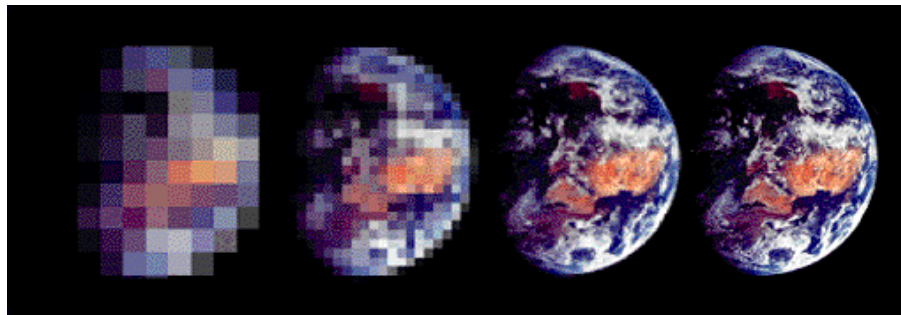
- Look for faint light, or heat, generated or reflected, by a planet
- This is difficult: small, dim planets are hard to see near big bright stars
  - *Have you ever looked into the high-beams of an oncoming car and tried to see the color of the driver's eyes?*
- The light or heat from the star needs to be blocked so the dimmer planets can be seen
- For now, we can only see very large companions (brown dwarfs) far away from a parent star



- Eventually we will take a family portrait of a planetary system by cancelling the starlight (this is easier to do in the infrared than in visible wavelengths)

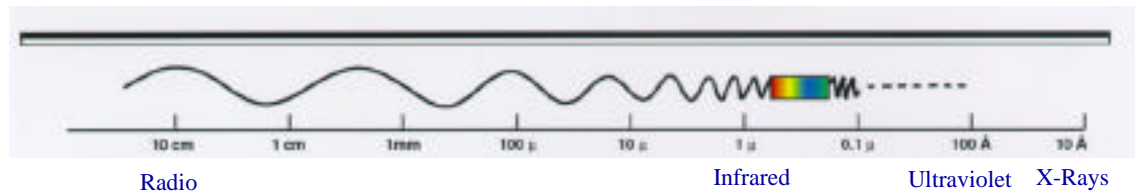


- Much further downstream we might be able to get an image of a planet

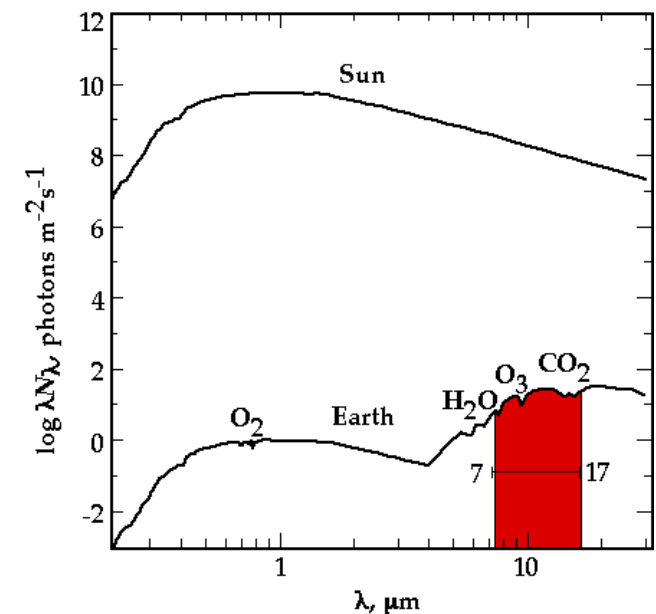
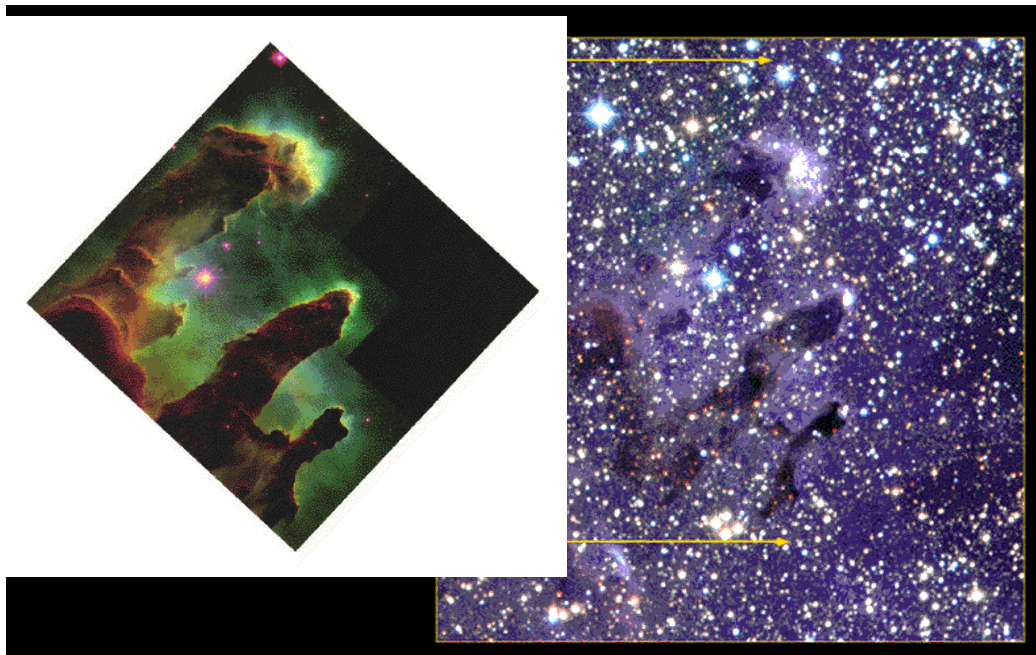


# Infrared: A different way of seeing

- Infrared is a portion of the electromagnetic spectrum that is associated with heat generated or reflected by an object
  - Think of “night vision” cameras



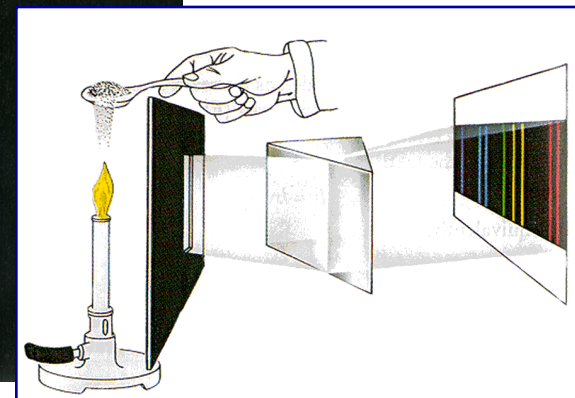
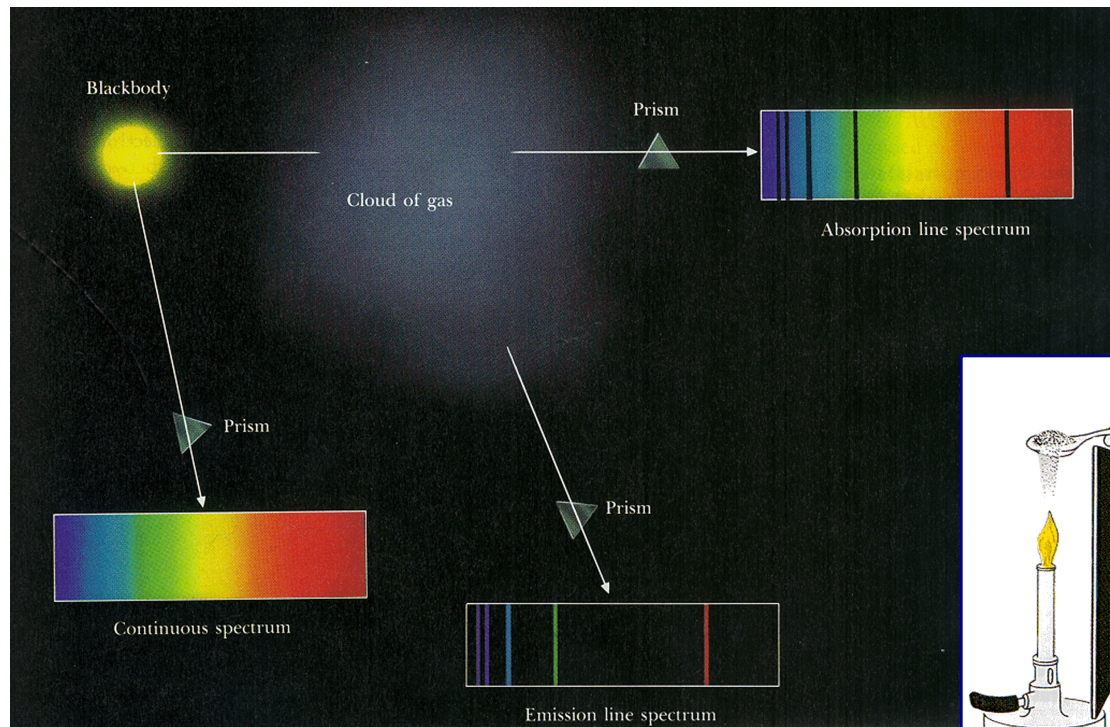
- Infrared allows us to peer through dense, dark gases to see hot stars, which cannot be seen in visible light



# **How Can We Tell if a Distant Planet Can Support Life?**

# Fingerprinting the Universe

- Light from a distant planet passes through the atmosphere of that planet before it reaches us
- Depending on what chemicals are in that planet's atmosphere, certain energies get absorbed
- When the light reaches Earth, we can tell from these absorption lines what chemicals are present in the atmosphere of the distant planet
- **Spectrograph** -- astronomer's high-tech prism

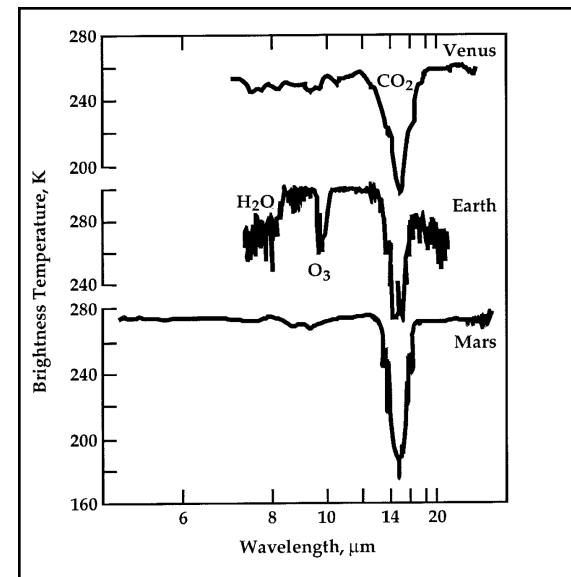
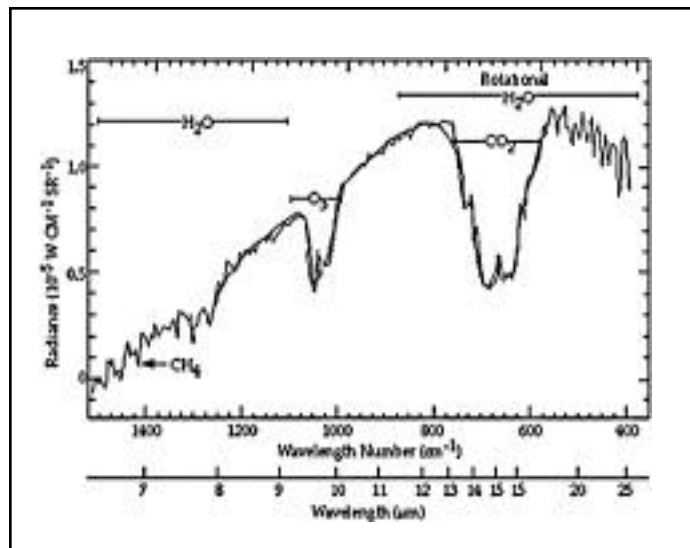


## How will we tell if a planet is habitable?

- We look for absorption lines of life-friendly chemicals, such as water vapor and oxygen

## How can we tell if a planet is harboring life?

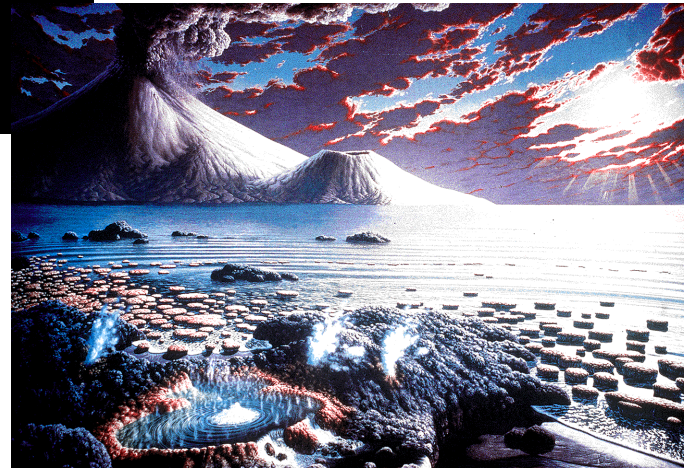
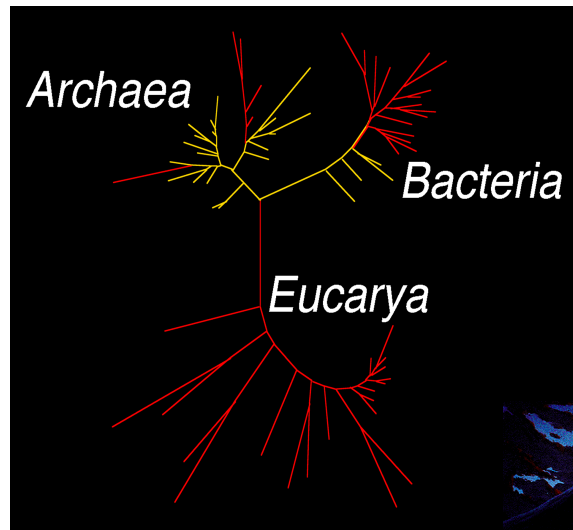
- We look for stuff that seems out place naturally -- too much oxygen, for example
- Oxygen is sociable -- it likes to bond with other elements rather than be free-form
- So, if we see a lot of free oxygen, something must be generating it -- such as plants on the planet?
- Another indicator of life is the combination of oxygen **AND** methane



- A microorganism early in Earth's history might be the common ancestor of all living things today
- Some lifeforms on Earth are very tenacious and can survive in extreme environments

# All Living Things on Earth Are Related

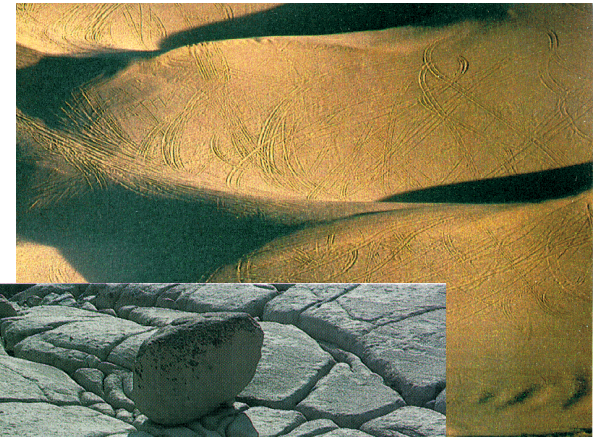
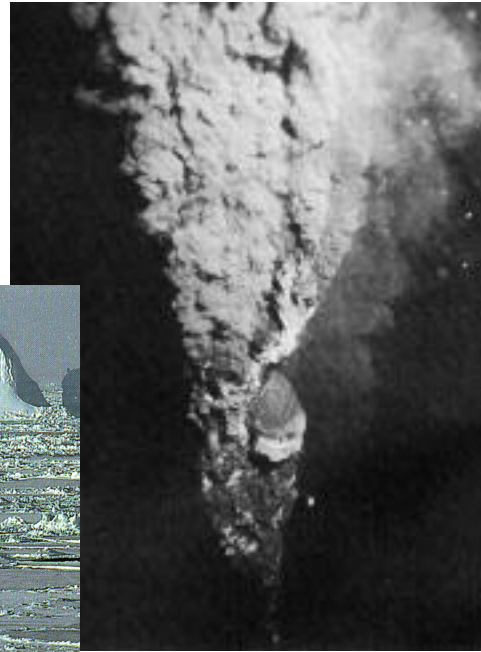
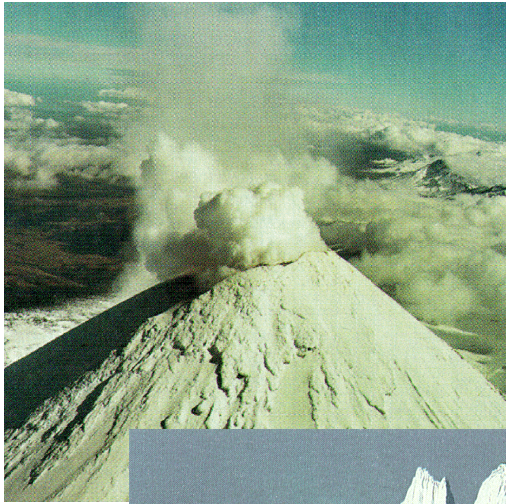
The whale, the enzymes in the baker's bread, and the baker himself can all be traced back (through the Universal Tree of Life) to a microorganism which first appeared very early in Earth's history.



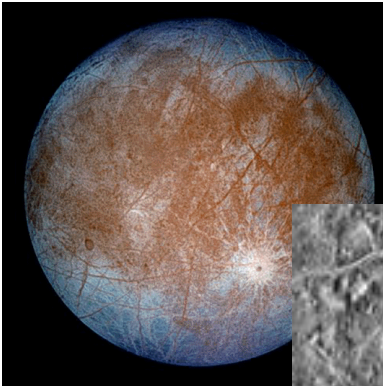
# Life in Extreme Environments

Life on Earth has been found in extreme environments -- places previously thought to be

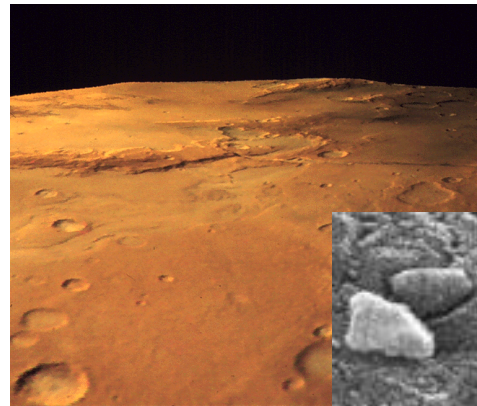
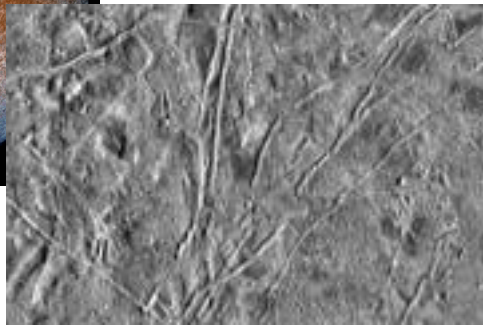
- far too hot
- far too cold, or
- far too dry



# Life Elsewhere in Our Solar System?



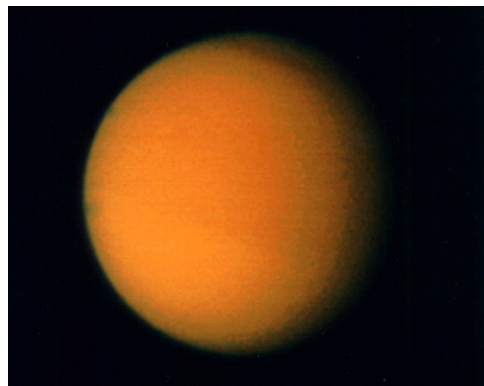
In an icy ocean on Jupiter's moon, Europa?



Hidden in frozen rocks on Mars?



Is this a fossilized Martian organism?

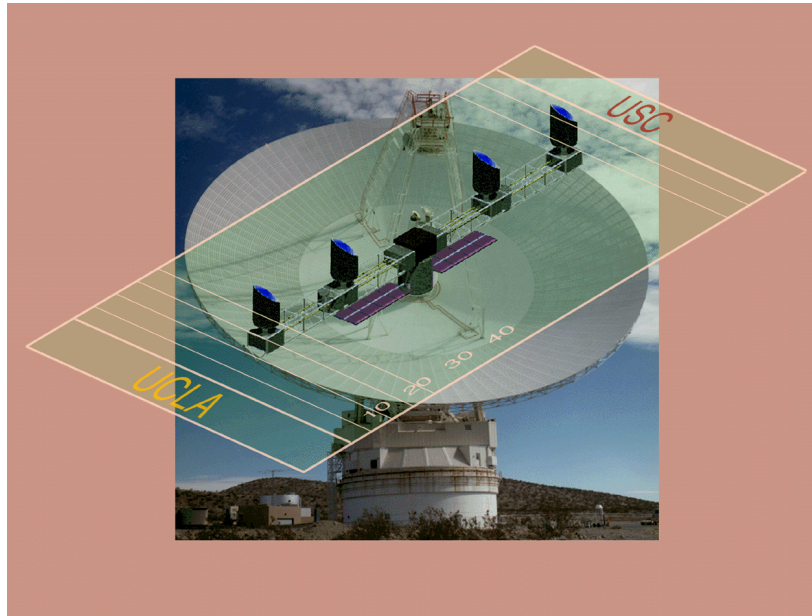


What clues to pre-biotic chemistry will we find in Titan's atmosphere?

**Interferometers: When  
Telescopes as Big as Football  
Fields are Too Expensive**

# Detecting Planets is Tough!

- **Planets are close to very bright, large objects -- their Suns**
  - Trying to see these planets is like trying to see a firefly in the glare of a nuclear explosion
  - We need to block out the bright light of the star so we can see the planet
- **Furthermore, distant planets are very small, dim objects**
  - We need extremely large telescopes to see them
- **How large is large?**
  - As big as a football field
  - But we can't launch something that heavy -- it's far too expensive
  - We need a better way
  - That's where **INTERFEROMETERS** come in



# What IS an Interferometer?

- It consists of a number of relatively small telescopes spread across some distance, either on the ground or in space
- Light collected from these telescopes is cleverly combined so the interferometer acts like a giant telescope.

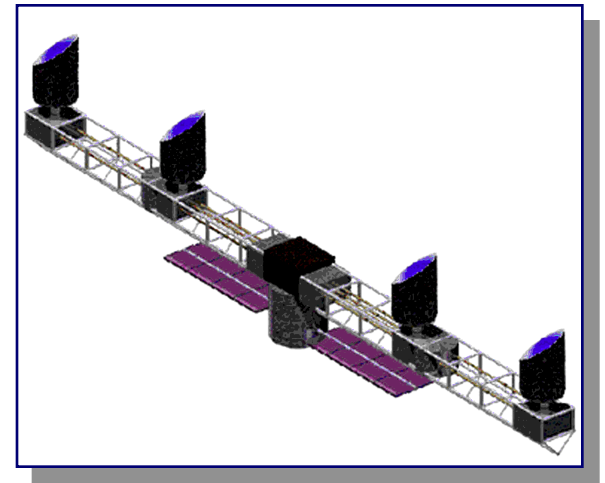


Can be several telescopes on the ground

Can be on one long boom (neatly folded to fit into a launch vehicle), OR



Can be placed on several spacecraft flying in formation



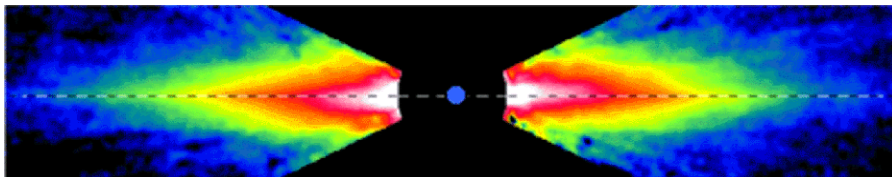
# **Origins**

## **Mission Gallery**

# Keck Interferometer

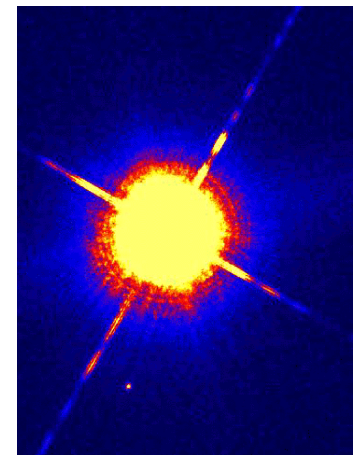


- Part of NASA's Origins Program, the two powerful Keck telescopes (85 meters apart) and smaller "outrigger" telescopes will be linked to form interferometers of various lengths
- Plan to begin observations in 2001

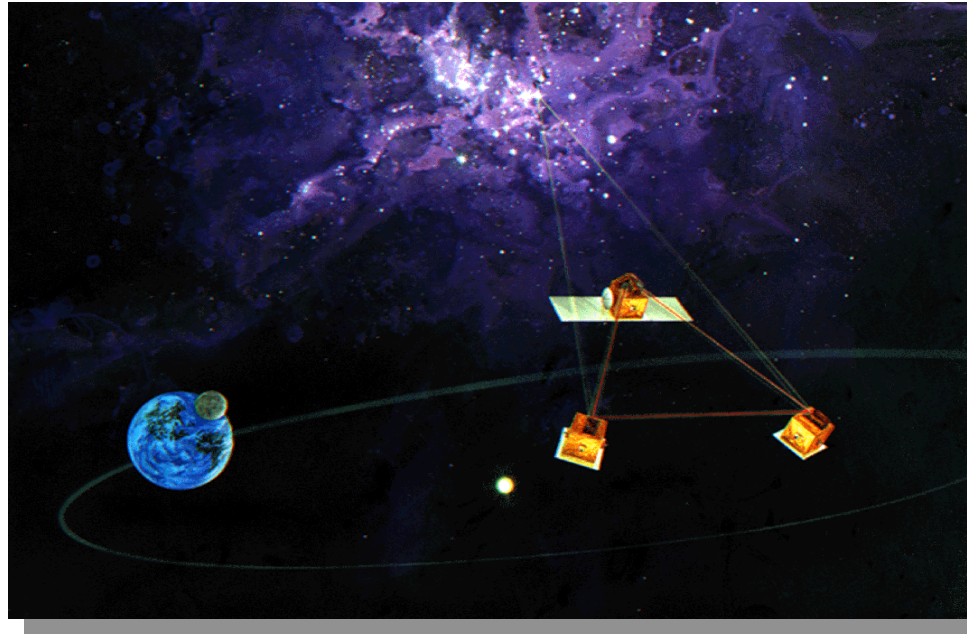


Measure dust clouds around other planetary systems

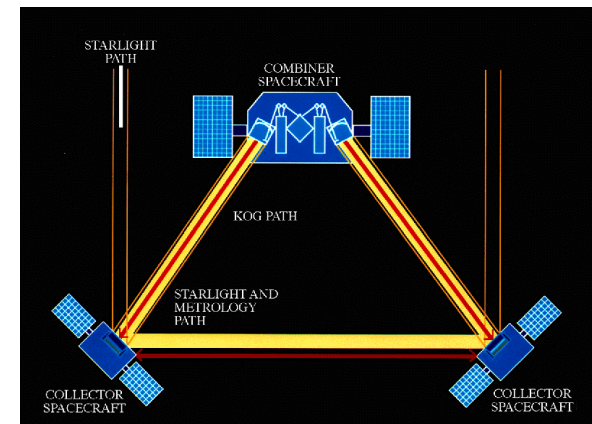
Directly detect planets  
hotter and larger  
than Jupiter



# New Millennium Deep Space-3 (DS-3)



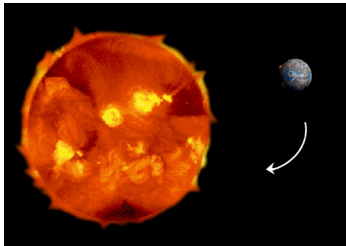
- The goal is to demonstrate technology needed for future interferometer missions
- Two spacecraft separated by approximately 1000 meters will form a long interferometer
- Light from these two will be collected by a third spacecraft
- All three will fly in precise formation -- to a few inches
- A joint mission with the German space agency
- Target launch date: 2001



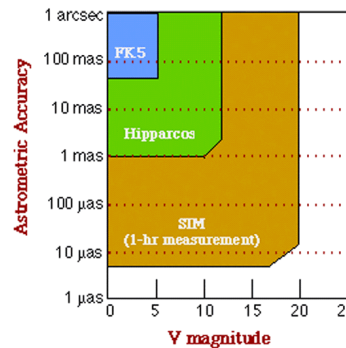
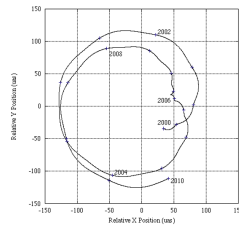


# Space Interferometer Mission (SIM)

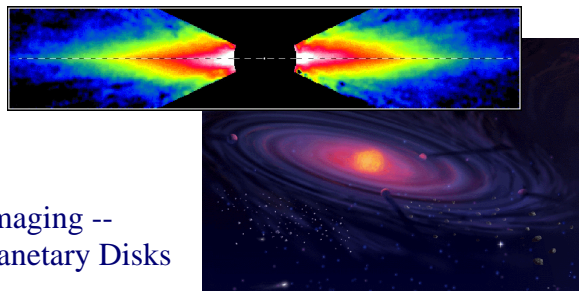
- NASA's first long-baseline optical interferometer
- Seven 33-centimeter star trackers combined to effectively mimic a 10-meter telescope



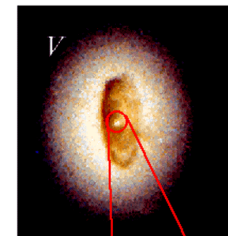
Indirect Detection of Planets through Observations of Thousands of Stars



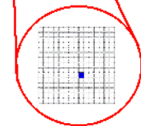
Age & Distances in the Universe  
Orders of Magnitude Improvement on Parallaxes in the Galaxy and Beyond



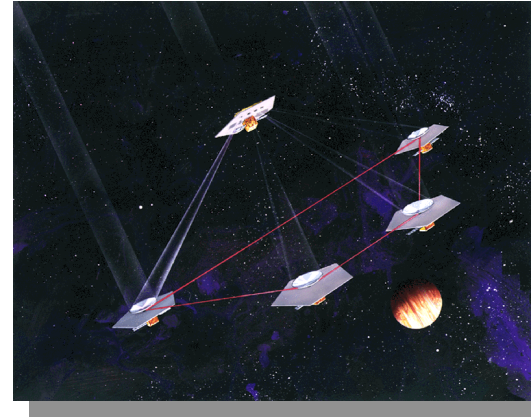
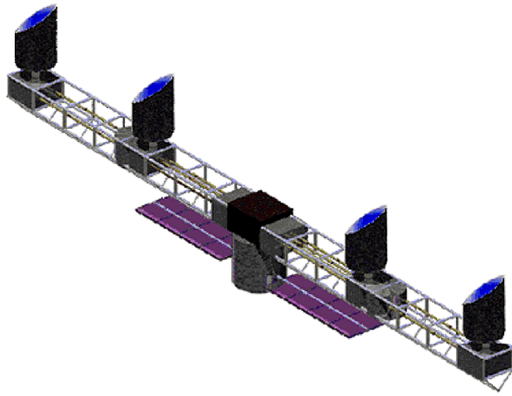
Nulling Imaging -- Structure of Planetary Disks



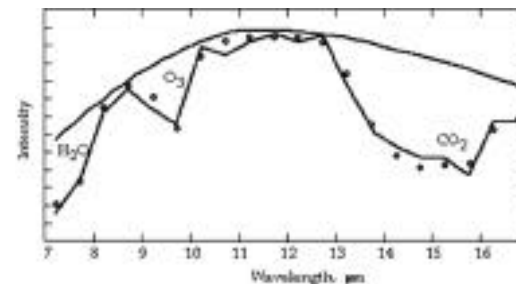
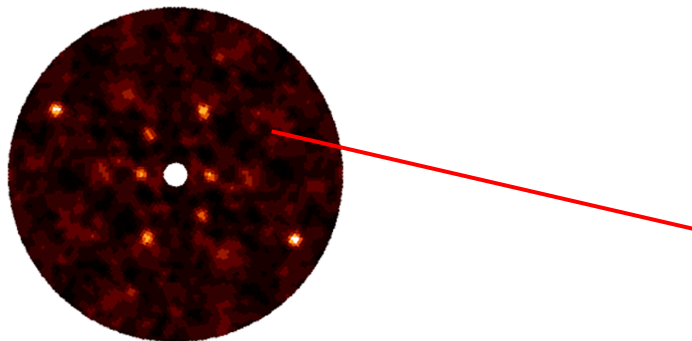
High Resolution Imaging -- 5 Times Better than HST on a Small Field of View



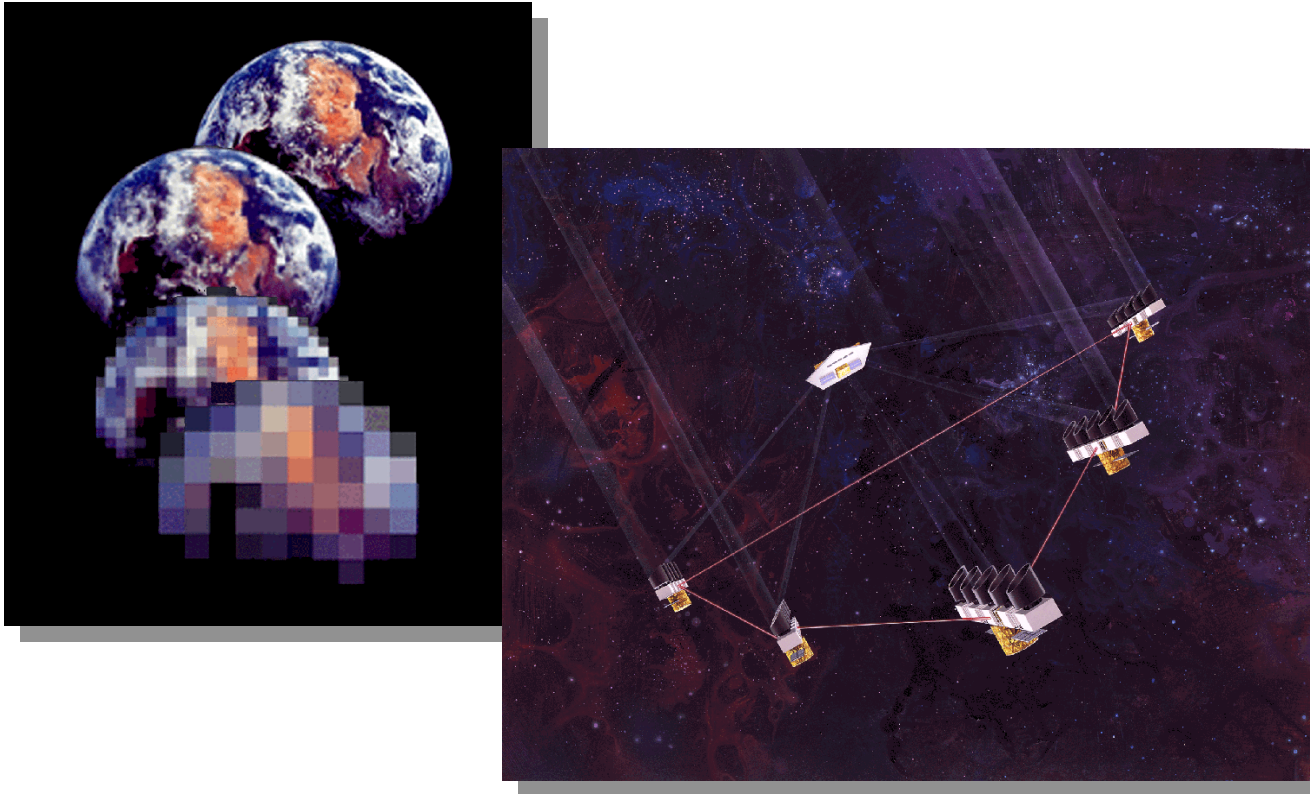
# Terrestrial Planet Finder (TPF)



- The goal is to take “family portraits” of other planetary systems -- that is, other “suns” and the planets around them
- We will examine 1000 stars that are nearest to us
- We will study the atmospheres of many planets to see if any other planets can support life ... or, if life already exists there
- The bright light from parent stars needs to be cancelled so we can see dim planets that may be around them
- We will need an interferometer as long as a football field -- maybe longer
- If a longer interferometer is needed, several spacecraft flying in precise formation, each carrying a telescope, will form a “virtual” interferometer
- Planned launch date: at the end of the first decade in the new century

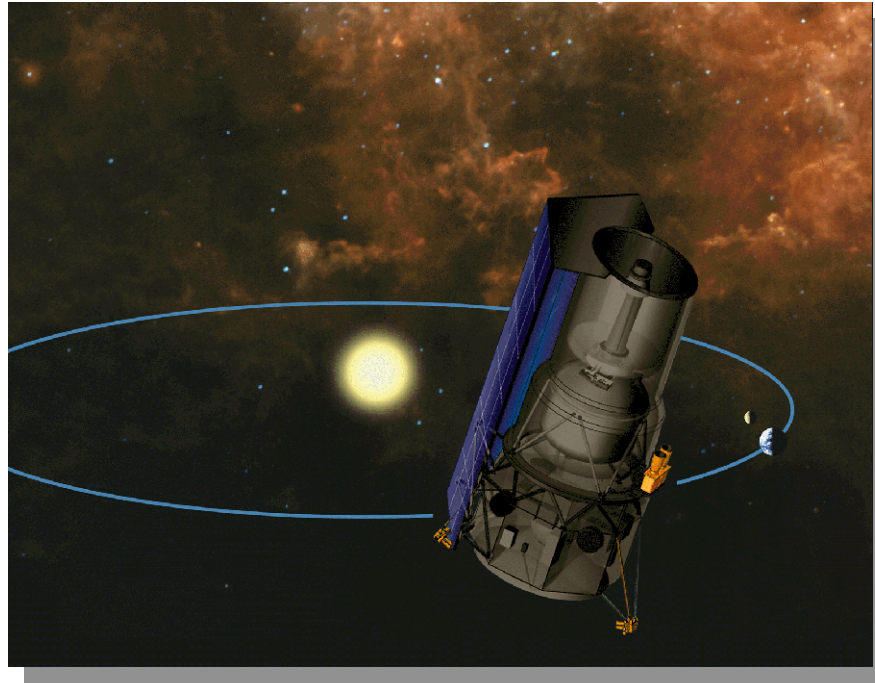


# Terrestrial Planet Imager (TPI)



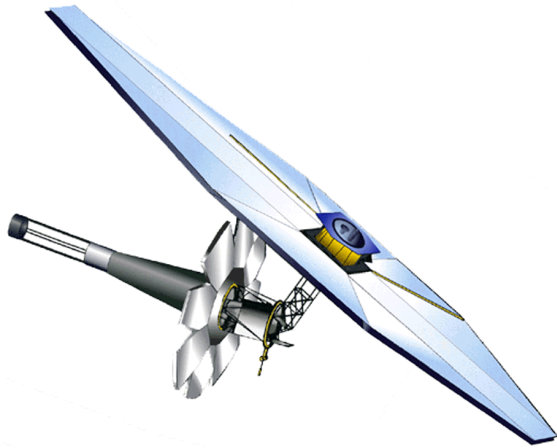
- The goal is to image an Earth-like planet
- It is the long-range goal of the Origins Program -- 20 to 25 years into the next century
- Four 8-meter telescopes will be arranged as an interferometer
- Five such interferometers will fly in precise formation
- The bright light from parent stars will be cancelled at each interferometer -- so that dim planets can be imaged
- Light from the five interferometers will be combined in a collector spacecraft

# Space Infrared Telescope Facility (SIRTF)



- Detection of young and forming galaxies
- Studies of formation of stars and planetary systems
- Characterization of dust clouds around solar-type stars
  - Contributes to the design of Planet Finder

# Next Generation Space Telescope (NGST)



- The goal is to see the universe when the first stars and galaxies were being born
- Follow the evolution of chemical elements in the universe
- The follow-on to Hubble Space Telescope
- An 8-meter mirror (Hubble has a 2.4-meter mirror) will give NGST ten times more light-collecting area--therefore, better resolution
- Goddard Space Flight Center (GSFC) is the lead center for NGST)
- Target launch date: a decade from now

